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ASPHALTUM

BY

J. W. HOWARD

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NATURAL ASPHALTUM

AND ITS COMPOUNDS,

Their Importance, Definitions, Mineralogy, Analyses,
Uses, History and Statistics.

A PAPER

Prepared for the use of the Professors and Students of the Rensselaer
Polytechnic Institute and others at the request of
the Rensselaer Society of Engineers

BY

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NATURAL ASPHALTUM AND ITS COMPOUNDS.*

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NATURAL ASPHALTUM

AND ITS COMPOUNDS.*

BY J. W. HOWARD, B. L., C. E.

I. IMPORTANCE OF ASPHALTUM.

The importance of an industry can be judged by its volume, value, usefulness and the kind and number of men employed. Every engineer, architect and constructor needs at least a general knowledge of the properties and uses of asphaltum.

This paper is intended to give simply and briefly an outline of those scientific and general facts about asphaltum, which are essential to technical pursuits.

The importance of the asphalt industries can be judged first, from the fact that there are more than 65 known mines and deposits; secondly, because it enters into constructions and preparations used in all branches of engineering and architecture, as well as in many manufactures.

There are employed in mining, shipping, refining, preparing and applying asphalt and its compounds, scores of graduates of technical institutions, hundreds of business men and thousands of laborers.

The volume of the industry is measured by the fact that the one branch of this industry, asphalt paving, is found in more than 92 American and 55 European cities. This means an investment of at least \$55,000,000 of municipal funds and a working capital, if combined, of at least \$15,000,000.

The growth of asphalt industries has been very rapid during the past forty years in Europe and twenty in America.

The men engaged in it have been too busy to write its complete

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history or a full treatise on the subject. Fragmentary articles, pamphlets, etc., in either German, French, Italian or English are available; each touching upon some mine or branch of the work. These are generally issued by commercial companies; while acting as advertisements they contain much practical information. Actual experience with asphaltum and its compounds is the best teacher, especially when guided by the recorded experience of others.

II. DEFINITIONS.

A series of precise definitions makes the best introduction, so that it shall be clearly understood just what is meant by the terms used.

(a) *Definition of Asphaltum.*—*Asphaltum*, called generally in English Asphalt, is the Latin for the Greek ἄσφαλτος (asphaltos).

It is a natural mineral pitch and is practically unchangeable at ordinary temperatures. When pure, or nearly pure, it is dark brown or black. When struck with a hammer at ordinary temperatures it is brittle. Its fracture is dull and conchoidal. It is sectile. When rubbed or freshly broken it emits a bituminous odor. Its specific gravity in its natural state is from .96 to 1.68, due to impurities and porosity. It is not soluble in water. It is soluble in carbon disulphide. It begins to melt at about 190° F. and flows at about 200° F. It is partly soluble in alcohol, turpentine, ether, naptha and petroleum. Its hardness at 70° F. is $2\frac{1}{2}$ to 3 Dana scale.

Asphalt is often called by other names, as Trinidad asphalt, Cuban asphalt, Bitumen, Jews' Pitch, etc.

The word asphalt, with slight changes in spelling, is common to all languages.

While asphaltum is a bitumen, all bitumen is not asphaltum, as will be explained in Sec. III. of this paper.

In Europe certain persons, probably for brevity, have called asphaltic limestone, "Asphalte" Asphalt simply saturates the limestone. This compound of limestone and asphalt should not be called asphalt.

In America, the public has been led into the error of supposing that the by-product of the gas works, namely, gas-tar and

coal-tar, were asphalts. This is due to the efforts of either unprincipled or ignorant persons, who have desired to sell coal-tar preparations, which, while they have valuable uses, should not be sold or used where asphaltum is needed. They are the products of distillation. The volatile oils contained in them, if exposed to the air or sun, soon disappear and black powder remains. Real asphaltum retains its fixed oils and cementing qualities, hence its lasting properties in its natural and artificial compounds.

Refined Asphaltum is the product resulting from the refining by heat, at a temperature below 400° F., of crude asphaltum. The water and vegetable matter are removed. Commercially refined asphalt used in engineering, architecture, etc., still contains some earthy matter. It is not necessary to fully remove this, because in the mixtures subsequently used it would be replaced when mixed with sand, limestone dust, etc., as occasion demands.

Asphaltic Cement is a combination of refined asphalt and residuum oil of petroleum of a standard specific gravity at a given temperature. The proportions used vary with the objects for which the asphaltic cement is prepared. From 15 to 18 lbs. of residuum oil is used to every 100 lbs. of refined asphalt. They are mixed hot and agitated by air or mechanical means.

(b) *Asphaltic Limestone*.—Asphaltic limestone is a natural compound of asphalt and limestone. Maltha, and other bituminous substances, are sometimes present. Sulphur, sand and a few other foreign substances are generally found in it. Its fracture is irregular, and its color is from brown to chocolate black when freshly broken. The color is darker in the specimens containing the larger amounts of asphaltum. The percentage of asphaltum permeating the limestone varies in different deposits, and in different parts of the same mine, from less than 1% to above 20%. The grain of asphaltic limestone is very fine. Under the microscope the smallest particle is coated with asphaltum. If cut by a sharp blow of an axe it appears grayish white along the cut, due to forcing out of the asphaltum and leaving particles of limestone exposed. If a piece contain above 10% of asphalt it can be warmed and broken in the hands. A piece heated over the fire falls apart. If heated in

a pan and held for an hour at a high temperature, the asphaltum is driven off and a gray, powdered limestone remains. A bituminous odor is perceptible in all samples when freshly broken if they contain above 4% of asphaltum.

Asphaltic limestone is sometimes called "rock asphalt" and "bituminous limestone." In France, while often referred to erroneously, as "asphalte," its real name is "calcaire bitumineux." The German name is "Asphaltekalkstein," and for brevity, "Asphaltstein."

(c) *Asphaltic Sandstone*.—Asphaltic sandstone is composed of sandstone containing from less than 1% to sometimes as high as 70% of asphaltum. Maltha and petroleum are often present to the injury of the asphaltic sandstone for engineering uses. This material is called by a few people in California by the name "asphalt rock," which is misleading. It has not yet proved itself very valuable. Experiments are being constantly made to establish its value and how to use it.

(d) *Asphalt Pavements*.—Asphalt pavements are of three classes, laid upon concrete or other suitable foundation, and composed of either Trinidad asphalt, sand, powdered limestone, etc.; or asphaltic limestone, or asphaltic sandstone, if laid upon roadways. But if laid upon walks, floors, roofs, etc., one or more of these materials are combined in various ways. I will define them separately.

Trinidad asphalt pavement, the standard of this class, is laid briefly as follows: The street is graded, rolled with a steam roller, supplied with a cement foundation, generally five or six inches thick. In case the street is covered with a Macadam roadbed or old stone-block pavement, these are often used as foundations without the hydraulic cement concrete. If Macadam or old stone-blocks are used for a foundation, a thin layer, about 1½ inches thick, of asphaltic concrete, called "binder" is first laid upon these old surfaces. The asphalt paving mixture, called the "wearing surface," is laid upon the foundations, prepared as described. The wearing surface is also laid on 1½ inches of binder spread over 5 inches of hydraulic cement concrete.

This wearing surface mixture is spread with hot rakes and compressed with a steam roller to the thickness desired, 1½, 2,

and in certain places, $2\frac{1}{2}$ inches thick, as the street and system of pavement demands. The Trinidad asphalt paving mixture is compounded as follows: Asphaltic cement is first prepared by mixing refined asphalt and residuum oil, using from 15 to 18 lbs. of residuum oil, according to the climate, etc. The asphaltic cement serves to cement together the sand and powdered limestone entering into the wearing surface mixture, which is as follows:

Asphaltic cement, ...	12 to 15% by weight.
Sand	83 to 70%.
Powdered Limestone	5 to 15%.

The mixing is done in a special toothed mixing apparatus, the teeth interlacing and revolving on two shafts in opposite directions. The asphaltic cement and sand are first previously heated to above 250° F., which is the temperature at which the mixture should be laid upon the street. The proportions vary according to the kind of sand used and the climate. The proportions of oil in the asphaltic cement, as well as the proportions of the materials in the paving mixture, vary with the climate. More asphaltic cement is used in cold climates than in warm ones. This easy adaptability to climate is one of the reasons of the success of this pavement.

Asphaltic limestone pavement is a pavement laid upon a suitable concrete or other foundation, and composed of powdered asphaltic limestone spread upon the foundation previously prepared, and compressed in position by hot iron rammers, or otherwise. The process is, briefly, thus: The asphaltic limestone is mined in large lumps, crushed in a suitable crusher, powdered while cold in an appropriate pulverizer. The powder is heated to a temperature a little above 275° F., spread upon the street and compressed in position. The natural asphaltic limestone, called sometimes rock-asphalt, must contain about 10% of asphaltum, more or less, according to the climate, for this class of paving.

Asphaltic sandstone pavement is a pavement of natural asphaltic sandstone, prepared, briefly, as follows: The material is mined, crushed by a crusher, if not fine enough when arriving from the mine, and then disintegrated by the injection of steam into the mass, or by passing the material through a revolving steam

heated jacket, or cylinder. The material, when fine, is raked upon the prepared foundation and compressed in position generally by a steam roller. Asphaltic sandstone pavements, because still in an experimental stage, have not yet definite percentages of asphaltum decided upon as final and best.

Asphaltic mastic is of three kinds. First, that which is composed of a mixture of powdered asphaltic limestone, Trinidad asphalt and possibly a little residuum or other oil; second, that which is composed of sand, possibly a little limestone dust and about 22% of asphaltic cement; third, that which is composed of crushed asphaltic sandstone, enriched by the addition of either asphaltic cement or a little maltha. All asphalt mastics are mixed or prepared hot, and generally run into molds varying in shape, at the different factories. These are called asphalt mastic blocks and are generally about six inches thick, and either round, square or hexagonal. They are shipped to the place needed and there remelted and used in making walks, floors, roofs and in many other ways.

Asphaltic Concretes are composed of either crushed stone cemented together with asphaltic limestone mastic; or of crushed stone cemented together with Trinidad asphalt mastic, that is, a mixture of crushed stone, sand, limestone dust and asphaltic cement, mixed hot and compressed in layers by hand. These concrete foundations have many uses.

The details of mining, preparing and using of asphalt and its compounds will be given in Section V., further on.

III. POSITION IN MINERALOGY.

(a) *Group of bitumens to which asphaltum belongs.*—It is best to pass at once to the position of asphaltum and its compounds among minerals, omitting the geology and origin of these materials, which form a special field of study and investigation not yet in tangible shape.

Among the hydro-carbons there is a group of minerals called the Bitumens, or bituminous substances, which, arranged in order of their density, are as follows:

TABLE NO. 1.

	1. <i>Natural Gas</i> ,
	2. <i>Natural Naptha</i> ,
	3. <i>Petroleum</i> , or Mineral Oil,
BITUMENS.	4. <i>Maltha</i> , or soft, sticky Bitumen, (at 77° F.,)
	5. <i>Asphaltum</i> , or stiff, non-sticky Bitumen.
	6. <i>Glance Pitch</i> , or dry, brittle Bitumen,
	7. <i>Elaterite</i> and others.

This list suffices to establish the position of asphaltum among bituminous substances. These bitumens are seldom found native or pure, but are mixed two or more together; also in combination with earth, clay, sand, etc. Sulphur, magnesia, carbonate of lime are often present.

(b) *Asphaltic compounds and occurrence by classes, deposits and countries.*—The grouping of asphaltic minerals and their distribution in the world can best be shown by means of a tabular arrangement. The following Table No. 2, while not fully complete, is the result of fourteen years' correspondence, reading and visits to asphalt mines. This is the first time that I have ventured to publish the same, and I hope it will help systematize the subject of asphaltum and its compounds. The volume of the industry is so great that standard definitions and systematic arrangement of materials are imperative.

TABLE NO. 2.

IMPORTANT NATURAL BITUMENS.	NATURAL GAS.	Ohio, Pennsylvania, California, etc., in the United States, Russia, France, etc.
		Found in petroleum districts (of little value, superseded by artificial naphtha from crude petroleum.)
		Pennsylvania, Ohio, Wyoming, California, etc., in United States, Russia, etc. (Consult books on petroleum.)
		California, Wyoming, Alabama, Utah, Colorado, Kentucky, New Mexico, Ohio, Texas, Indian Territory, etc., Russia, France, Germany, etc.
	ASPHALTUM.	North America. . . Utah, California, Texas, etc.
		Central America.. Cuba, Mexico, etc.
		South America. . . Trinidad, Venezuela, Peru, Columbia, etc.
		Europe. Caucassia, Syran on the Volga, Germany, France, Italy, Austria, etc.
		Asia. Hit on the Euphrates, Asia Minor, Palestine, etc.
		Africa. Oran in Egypt, probably other places.
		North America. . . West Virginia, Kentucky, Texas, Wyoming, Utah, Colorado, California, Indian Territory, Montana, New Mexico.
		Central America.. Mexico, Cuba, etc.
		South America. . . Trinidad (largest supply, most used), Venezuela, Peru, Columbia, etc.
Asphaltic Compounds	Asphaltic Compounds	Europe. Germany, Switzerland, France, Italy, Sicily, Russia, Austria, Spain, etc.
		Asia. Asia Minor, Palestine, Bagdad and probably in China.
		Africa. Egypt and probably elsewhere in Africa.

In order to facilitate reference, I have arranged the principal deposits of asphalt and its compounds, by materials and countries or states, in the following :

TABLE NO. 3.

ASPHALTUM.

Mixed With Earthy Matter.	Compounded With Lime-stone.	Compounded With Sand-stone.
Bagdad, California, Colorado, Columbia, Indian Territory, Mexico, Montana, Palestine, Peru, Texas, Trinidad, Utah, Venezuela.	Austria, California, Dalmatia, France, Germany, Hungary, Indian Territory, New Mexico, Michigan, Italy, Russia, Sicily, Spain, Switzerland, Texas, Utah, Washington.	California, Colorado, Cuba, France, Germany, Indian Territory, Kentucky, New Mexico. Russia, Texas, Utah.

Other bitumens, as maltha, etc. ; and impurities, as sulphur, etc., are often present, sometimes to the commercial detriment of the material. One or more mines are worked in each of the above countries, except, perhaps, Columbia, Indian Territory, Montana, New Mexico, Michigan, Washington and Dalmatia.

IV. ANALYSES AND TESTS.

(a) *Chemical*.—Without entering into the complicated details of the analysis of hydro-carbons and bituminous substances, I will first call attention to the complete chemical analysis of specimens of asphaltum into their elements from representative deposits in the world. This is shown as follows : in

TABLE NO. 4.

Place	Trinidad.	Mexico.	Peru.	Cuba.	Columbia.	Palestine.
Carbon	85.89	80.34	88.67	81.50	88.31	80.00
Oxygen	.56	10.09	1.65	8.90	1.68	.40
Hydrogen	11.06	9.57	9.68	9.60	9.64	9.00
Nitrogen					.37	10.00
Sulphur	2.49					.60
Ash						
Totals	100. %	100. %	100. %	100. %	100. %	100. %

The above Table of the analysis of specimens of asphaltum is that of chemically refined asphaltum. This sort of analysis, while interesting has very little practical value. The commercial value of an asphalt depends principally upon its physical characteristics, which I will give later. Experience has shown that while chemical analyses are of great value in connection with asphalt industry, nevertheless they must be made upon special lines of investigation. We would proceed as follows: (and I take it for granted that my readers are familiar with the general principles and methods of qualitative analysis, and are able to appreciate, if not personally execute, quantitative analysis), having one or more samples of crude asphaltum to be examined, the first thing to do is to turn to the definition of asphaltum, Section II., heading (*a*), and compare the sample or samples with the characteristics set forth in the definition. See if it remains brittle and retains its form at ordinary temperatures of the air. Is it dark brown to black? Is it brittle when struck? Conchoidal? Sectile? Break it and see if it has a bituminous odor? Specific gravity about 1.00 to 1.68? Is it not soluble in water? Do not be deceived by the clay or other matter being soluble in water. It should begin to melt at 190° F., and flow at a little above 200° F. See if the hardness at 70° F. lies between 2½ and 3 Dana scale.

Dessicate a piece *in vacuo*, keeping the temperature below 212° F. Dissolve out the asphaltum from the crude material with carbon disulphide. Try the solubility of pieces in alcohol of standard specific gravity, in turpentine, ether, petroleum, naptha. By taking a little time, with the assistance of the sand bath, the distillation tests can be made at given temperatures

and for given periods of time. It is well to get the ash of each crude sample by combustion. The penetration tests can be made upon different samples of refined asphalt at constant temperatures a little above the temperatures used in making penetration tests upon samples of asphaltic cement.

The expert chemist will think of additional tests. What I have given above is in the way of suggestions to facilitate the comparison in a laboratory of different asphalts.

While the above chemical experiments and investigations are of great value in indicating the advisability of trying an asphalt from a new source of supply in pavements or other branches of engineering, nevertheless the only safe test is to finally try the asphalt in actual practice, keeping carefully tabulated records of what is done, and finally of the results of the asphalt pavements, mastics, concretes, or other construction into which the new asphalt was introduced.

I will omit the experiments upon asphalts with the spectro-scope, in which I am taking great interest. Possibly, in the future, I may try to tabulate the results in this interesting field of asphalt investigation, as yet so little developed.

(*b*) *Physical*.—As each student of science knows, the physical and chemical characteristics of a material are so interlaced that it is difficult to treat of them separately. Hence some of the physical characteristics and tests are contained under heading (*a*) above, because chemistry is necessary to, at least, in part, establish the physical properties.

The physical characteristics of the three principal asphaltic substances, asphaltum, asphaltic limestone and asphaltic sandstone are best given separately.

Trinidad asphalt supplies more than 90% of the asphaltum used in the world. It should therefore be described in detail, being, as it is, a standard asphalt and a type of all. Trinidad, an island at the mouth of the Orinoco, north coast of South America, is the property of Great Britain. Upon this island is found the "Trinidad Asphalt Lake," often referred to as the "Pitch Lake." It is a large, flat crater or deposit of asphaltum, mixed with much earthy and a little vegetable matter and water. This deposit is the property of the British Government. It is about a mile from the Southwest corner of the island, and covers almost 116 acres. The surface is hard, very slightly undulating, intersected by shallow cracks, covered at spots with

low temporary vegetation and pools of water. The asphalt is softer as we approach the centre, where it is very soft.

Leaving the description of gathering this material in carts driven upon the deposit, hauling it to the shore, loading it in vessels, refining it in America or Europe, until we reach Section V., where details of mining, etc., will be given, we will pass at once to the description of Trinidad asphalt.

Crude Trinidad Asphalt is dark brown and very brittle at ordinary temperatures. It is easily detached from the surface of the "Asphalt Lake" with a pick. Its irregular fracture shows particles of clay and vegetable matter in it. When warmed in the hand it can be slightly bent. When broken it emits a bituminous odor. It is very porous. The chemical and physical tests indicated above and by the definition of asphaltum are easily made.

The average analyses of crude Trinidad asphalt are as follows:

TABLE NO. 5.

First, by weighing, then driving off the water:

Authority, Richardson.

Water	27.85
Asphalt, earthy and vegetable matter.	72.15
	100. %

Second, analyzing the dry, crude asphalt:

Asphalt	52.87
Earthy and vegetable matter	47.13
	100. %

Third, combining results gives average analysis of crude Trinidad asphalt.

Asphalt	38.14
Earthy and vegetable matter	34.01
Water	27.85
	100. %

Finally the complete analyses of the materials contained in crude Trinidad asphalt are as follows:

Authority,	Bowen.	Richardson.
Asphalt	39.83	38.14
Earthy matter	33.99	26.38
Vegetable matter	9.31	7.63
Water.	16.87	27.85
	100. %	100. %

These are mechanical mixtures. The variation in water is very great. A lump of crude asphalt in a room loses its water in a few weeks. Powdered crude asphalt loses its water by evaporation in a few days. Samples of asphalt from the centre of the "Lake" vary slightly from those near the shore. But for commercial uses the asphalt from within the Asphalt Lake is more constant, reliable and better than that which, for a short time, came from places outside of the "Lake," and was known as "overflow or land pitch." This material contained many variable impurities, and lacked cementing qualities. It is no longer imported into the United States.

Asphaltic limestone has many physical characteristics, due to the various compositions of this material in the same and different mines throughout the world.

The definition of asphaltic limestone, already given under Section II., heading (b), indicates many of the characteristics of this material. The analyses of representative asphaltic limestones from four mines is shown in the following :

TABLE NO. 6.

COMPOSITION.	Val de Travers, Switzerland.	Seyssel, France.	Ragusa, Sicily.	Limmer, Germany.
Asphaltum	10.15	8.15	8.92	14.30
Calcium Carbonate . . .	88.40	91.30	88.21	67.00
Clay and Iron Oxide. . .	.25	.15	.91	) 17.52
Sand	. . .	. . .	.60	
Magnesium Carbonate . .	.30	.10	.96	) . . .
Insoluble	.45	.10	. . .	
Loss	.45	.20	.40	1.18
Total	100. %	100. %	100. %	100. %

These analyses are made by the usual solutions in re-agents of qualitative and quantitative analyses. There are many other mines and deposits, varying greatly in the proportions of asphaltum, calcium carbonate and sand present. Traces of many other substances are often found. A little water is generally present; sulphur sometimes appears. It is difficult to distinguish the petroleum and maltha if these happen to be present. This is done, generally, by dissolving out the bituminous substances in the bituminous limestone by means of carbon disul-

phide, then separating by evaporation at a very low temperature just above the temperature of the air, the carbon disulphide from the bituminous substances. The separation finally, of the bituminous substances present into petroleum, maltha and asphaltum can practically only be indicated by a series of distillations at given temperatures, increasing the temperatures according to the amounts at which the substances desired are known to be distilled. This analysis of one bitumen from another, that is asphaltum from petroleum, is exceedingly difficult and can only be undertaken by special chemists in well-equipped laboratories.

A piece of asphaltic limestone lying exposed and undisturbed for several months, appears upon its surface of a grayish white color. When prospecting for this material this should be borne in mind, for the undisturbed outcroppings of a ledge or deposit of asphaltic limestone is always gray or white. I attribute this to the chemical and physical action of the carbonic acid gas, moisture and air of the atmosphere assisted by the sun. These agencies disintegrate the surface of the limestone, leaving it covered with a light gray film.

Asphaltic sandstone is found in nature sometimes dense and sometimes soft. The grain varies in some mines from very fine to others where it is very coarse. Small particles of clay and other substances are often present. Little shells, of several kinds, are frequently found. Its color is almost invariably black. A piece heated upon a stove quickly falls to pieces if above 6% of asphaltum is present. Asphaltic sandstone very often contains petroleum and maltha in large quantities. In America, where crude asphaltum is cheap, it does not pay to extract the asphaltum from the asphaltic sandstone, as is done at a few places in Europe.

(c) *Detection of coal-tar, distillates and other imitations and adulterations.*—Just after the success of asphalt pavements in Europe and the consequent reports sent to this country, a desire arose to have smooth and noiseless pavements in American cities. At that time the public did not know what asphalt was, and because of the expense of transporting asphaltic limestone from Europe to America, many artificial compounds and imitations were proposed. Before long that which was previously known as gas-tar or coal-tar began to be sold under the name “asphal-

tum." Tar was mixed with sand and gravel, first for walks and then for roadways. These mixtures were called "asphalt walks" and "asphalt pavements." This went so far that at the time of the Tweed ring in New York City, many streets were spread over with coal-tar imitations of asphalt pavements, which were soon called "tar poultice pavements" and rapidly disintegrated. The use of coal-tar preparations for pavements of streets has almost ceased. It is still too extensively used for roofs in this country, whereas, in Europe it is not used at all, except, perhaps, in cases of small temporary sheds where a temporary substance, like coal-tar, is admissible.

The real names of these coal-tar products, manufactured by re-distilling the by-products from the gas-works, are "coal-tar distillates," and they are numbered distillate No. 1, 2, 3, etc., according to their comparative density. A name sometimes given them, probably to hide their origin, is "bituminous cement."

These artificial coal or gas-tar products have legitimate uses; but they cannot take the place of natural mineral asphaltum. Coal-tar must not be used as an adulteration of asphalt or its compounds.

Asphalt and coal-tar differ in origin, composition, odor and fracture. A general similarity in appearance deceives a few, especially when some asphalt is mixed with the tar.

"Paving-pitch" is another name given to coal-tar, especially when it is used for pouring between granite paving blocks, and otherwise in pavements. Coal-tar, a product of distillation of the gas-works, when exposed to water, air or the sun soon loses by evaporation its volatile oils and becomes a dry powder.

Genuine natural asphaltum retains its oils, hence its lasting qualities in pavements, concretes, etc.

A practical method to tell asphalt from coal-tar is as follows: Apply to any gas-works or coal-tar roofer and get a piece of coal-tar. Then apply to some dealer in natural asphaltum for a sample of refined Trinidad or other asphaltum. Having two samples, one of coal-tar and one of asphalt, place them side by side. The coal-tar emits a sharp, acrid odor, easily perceived. The asphalt must be rubbed hard to emit a strong odor. The asphalt odor will be quickly learned. It is entirely different from the coal-tar odor. The asphalt odor is known as a

“bituminous odor.” It is rather agreeable, perhaps a little sour smelling. Crude and refined asphalt, when quite cold, emits a weak, clay-like odor. Next taste one sample, then the other. Then attempt to chew a little of the refined asphalt. It will crumble. If it be an “asphalt paving cement,” made from genuine asphalt and residuum oil of petroleum, a fairly agreeable chewing gum is the result. Any attempt to chew coal-tar will result in disaster to the teeth, for it is very sticky and hard to remove from the teeth.

Next turn to the definition of asphaltum Section II., and to the analyses and tests of asphaltum Section IV., and apply the tests there suggested. The differences between gas-tar and asphalt will be at once apparent.

Expert analysis of mixtures to detect any coal-tar present, if present in small quantities, is exceedingly difficult, but when large amounts of tar are present in the mixture, they are quickly discovered by the sharp odor and otherwise. Much pavement was laid in one or two cities under the name “vulcanite,” which was a mixture of about 25% of asphalt and 75% of coal-tar, mixed with sand, powdered limestone, etc. This material is no longer laid where engineers have full control as to what shall enter into the pavements, unless they are influenced by other reasons than technical ones

Asphaltic cement is generally composed of refined asphaltum and residuum oil of petroleum, but at some places a mixture of asphaltum and maltha is being tried, with the promise of possible success. The questions of sufficient and constant supply of a standard grade of maltha enter into the problem.

This mixture of asphalt and maltha should not be regarded as an adulteration, simply an experiment.

Mixtures of asphalt and crude petroleum or asphalt and certain shale oils are not suitable for engineering purposes and must be avoided.

V. MINING, PREPARATION AND USES.

It is best to treat of the mining, preparation and uses of the three substances separately, because they are mined, prepared and used in different ways.

(a) *Trinidad asphalt as a standard*, comes from the Island of

Trinidad, and from the Trinidad Asphalt Lake upon that Island, as described in Section IV. under heading (*b*).

The carts and horses used to haul the crude asphalt from the deposit to the shore, drive upon the "Pitch Lake." The material, which has already been described as dark brown, brittle and similar to dense, dry peat, is picked loose, thrown into the carts, hauled to the ocean beach, loaded upon scows and lighters and thence into the steamers and sailing vessels which bring it to America or take it to Europe.

The excavations made on the surface of the deposit soon disappear by being filled up with new material from the sides and bottom.

Upon arrival at a refinery in the United States or Europe it is either unloaded and stored up for future use, or conveyed directly into large refining tanks, called "asphalt stills," which are, in brief, cylindrical retorts set in brick work and heated by indirect fire.

The crude asphalt is heated somewhat above boiling water and not above 400° F., for several days. By a few improvements this refining has been reduced to half the time it used to take. This process drives off the water, certain light volatile oils and gases. The vegetable matter floats and is disposed of. A part of the earthy matter settles to the bottom. The product is refined Trinidad asphalt and is drawn off into light barrels with one end out. This refined asphalt is sent by rail or boat from the several refineries to the many cities using it.

A full description of refined asphalt has been given in Section II., heading (*a*), under its definition.

The uses of refined asphalt are many and varied. In engineering constructions, generally speaking, it forms the basis of asphaltic cement, although sometimes used otherwise. This asphaltic cement is valuable where a cementing material is needed which is not affected by water, jarring, slight movements and weather temperatures, when used in connection with other materials, in pavements, bituminous foundations for steam hammers, dynamos or other rapidly revolving machinery. For the same reason it is valuable for roofing, especially where the roof is needed for a promenade or other foot traffic, for upper floors of buildings needing durable and water-proof floors, as in stables with the horses upon the

upper floors, granaries, etc., in connection with water-proof tunnels under rivers, as at Chicago, in powder magazines and other military constructions where earth-works cover the masonry, in reservoir linings, in natatorium linings. One of the most valuable applications of asphaltum, and more valuable than realized at first thought, is in connection with "damp courses" in buildings. A damp course, I may explain, is a course of asphaltic cement, either alone or in connection with fine hot sand or gravel, laid over the entire upper surface of a foundation on a line just above the earth. The first layer of bricks, preferably heated, is laid upon this damp course, which thus intervenes between the foundation and the upper construction of a building, preventing moisture from below ascending the walls, as takes place in almost all buildings when there is no damp course to prevent it. If, in addition to this, the outer surface of the foundation is coated with asphaltic cement and the cellar floor covered with, first, a little hydraulic cement concrete and then a layer of asphaltic mastic, a thoroughly dry building results.

Asphalt, as well as maltha and gilsonite, are valuable as a basis for coatings for iron pipes. They are not slowly soluble in water, as is the case with coal-tar products. All specifications for the dipping of iron pipes and many other kinds of iron should demand that this be done in hot natural asphaltum, or its equivalent, made from gilsonite, asphalt, maltha or some mixture of these to suit the case.

Electric, mining, mechanical and naval engineering consume large quantities of asphalt.

With a knowledge of the properties of asphaltum and its compounds, the working engineer will be enabled to produce results which otherwise would perplex him beyond measure.

Trinidad asphalt pavements absorb more than 90% of the asphalt imported from Trinidad. This pavement is laid, briefly, as follows: The street is graded, rolled with a steam roller, supplied with a suitable foundation and then covered with a layer of a mixture of sand and powdered limestone, held together by asphaltic cement. A full description of Trinidad asphalt pavement has already been given under Section II., heading (d).

The volume and importance of this class of pavement can be

judged from the fact that it is found in 72 American cities, covering an area of almost 14,000,000 sq. yds., on January 1st, 1894, equivalent to more than 911 miles of roadway, laid in sixteen years by thirty contractors or companies.

(b) *Asphaltic limestone* is mined either by open quarrying or by tunneling. In warm weather open quarrying is difficult because of the tenacity of the material. Tunneling is carried on sometimes by drills and wedges alone, but generally with powder. Gas is not to be feared in most asphaltic limestone mines. Water, however, often appears and must be constantly pumped out. It is mined in large lumps, crushed generally in a rotary, toothed crusher into pieces three inches and less in size. These pieces are passed through a pulverizer, generally the centrifugal type, sometimes in cylinders revolving and containing loose cast steel balls. The resulting powder is about as fine as mustard seed. It is stored up, preferably under cover, for future use, unless needed at once.

One of the chief uses of this powder is for laying compressed *asphaltic limestone pavement*, known generally as "rock asphalt pavement," and like other pavements into which asphaltum enters, it is called, simply, "asphalt pavement." While technically incorrect, practically it is proper to call a pavement containing asphaltum, an asphalt pavement, because though asphalt forms but from 10% to 15% of the mixture, it is the characteristic which determines the name of the pavement.

The process of laying asphaltic limestone pavements is, briefly, as follows: The powdered material is heated to about 275° F., either upon flat hearths or in revolving heaters. It is hauled to the streets in ordinary wagons, raked to such a depth over its concrete foundation that, when compressed by heated rammers or otherwise, it will have the required thickness, generally two or two and one-half inches. This form of asphalt pavement for streets is not popular in the United States, and appears at but few places in cities near the Atlantic Coast.

Asphaltic limestone street pavements, like all limestone, become polished and prove somewhat slippery under heavy fog or a light rain. They are also slippery in clear, cold, dry weather when clean. The class of asphalt pavement known as "Trinidad asphalt pavement," and others made on this system, are not slippery at any time, except when covered with a sheet

of ice. This is due to the fact that Trinidad asphalt pavement is composed of about 80% of sand, making it gritty and not susceptible of becoming polished. Paris, London and Berlin keep large supplies of sand at several points near the streets paved with asphaltic limestone, for use during times of fog, slight rain, snow and ice. This is not necessary and is not done upon streets paved with Trinidad asphalt pavements, nor with pavements composed of asphaltic sandstone in California.

Asphaltic mastic, called often simply asphalt mastic, is made as follows: The powdered asphaltic limestone is heated in revolving retorts, refined Trinidad asphalt is added until the mass contains about 20% of bituminous substances, including the original asphaltum, etc., in the asphaltic limestone. The melted mass is constantly stirred until run off into moulds. The mastic blocks or cakes thus formed are shipped all over the world.

The preparation of the mixture for sidewalks, floors, roofs and other applications of asphaltic mastic is as follows: Put a little refined Trinidad asphalt in a large kettle, about 7 lbs., when melted add 100 lbs. of mastic, stir while heating. When soft add sand or fine gravel little by little up to 60 lbs., as the nature of the work demands. Where necessary, several hundred pounds, even thousands of pounds can be mixed at one time. The amounts given indicate the proportions. The mixture, when ready, is taken from the melting kettles, spread upon the surface to be covered by means of thick wooden spatulas or trowels and rubbed down with pressure, by hand. The surface is finally covered with fine white sand, which is also rubbed over the finished walk, floor, etc.

Asphalt mastic, when warm, is like a soft mortar, and can be used in many ways to great advantage. When cold it is slightly pliable and thoroughly water-proof. It can be thickened by the addition of fine sand or powdered limestone for uses in places subject to the direct heat of the sun, etc.

This form of asphalt mastic is used upon the roofs of all modern public buildings of Europe, and in many of America, where the roofs are flat or almost flat. It is the official sidewalk of the streets of Paris, where almost 1200 miles exist. One reason for this is because most of the pipes being under the

sidewalk the asphalt walk is easily removed and quickly replaced. It is without joints and easy to walk upon.

Asphaltic mastic made from asphaltic limestone, asphalt, etc., as well as that made from fine sand, powdered limestone and Trinidad asphalt, is used in almost every branch of engineering and architecture.

(*c*) *Asphaltic sandstone*, the third class of natural compounds of asphaltum and other minerals, has as yet but little value. It is quarried generally by blasting. It is seldom, if ever, mined in tunnels. The definition of this material found in Section II., heading (*c*), shows that it is very variable. The additional characteristics of this material already described in Section IV. at the latter part of heading (*b*), indicate the possible uses, not yet fully determined, to which asphaltic sandstone may be applied.

Asphaltic sandstone pavements are laid as indicated in Section II., heading (*d*), under the definition of this class of pavement.

VI. HISTORY OF ASPHALTUM AND COMPOUNDS.

(*a*) *Ancient times*.—The briefest reference to ancient times will suffice. Asphaltum is mentioned by the Arabic writers under the name “chemar,” by the Greeks ἀσφαλτος (*asphaltos*), by the Latin writers as asphaltum, and sometimes by its generic name, bitumen.

It was used in Egypt in connection with embalming the dead, as found in mummies. They got their supply, in part, from Is, modern Hit, near Babylon and near modern Bagdad, which mines are still worked. Refined asphaltum 60 minæ in weight was a part of the annual tribute sent during the years just previous and subsequent to 525 B. C. from Babylon to Egypt.

The Bible, in Genesis, relates in connection with the Tower of Babel (near Babylon), as follows: “Asphaltus fuit eis vice coementi” (asphalt was used by them for cement). Concerning Noah’s Ark we read: “Bituminabis eam bitumine,” which reads in the English Bible: “Pitch it with pitch.”

There are many places where the substance is mentioned in the Greek and Latin Bibles under the names indicated. The

use of asphalt was clearly known in ancient times, as indicated by the writings of Pliny, Virgil, Curtius, Ovid and others. Herodotus described the use of asphalt in the construction of the walls of Babylon. Diodorus gives details of the use of asphalt for cement, especially as poured upon reeds, laid cross-wise the entire thickness of these walls, thus binding them transversely. When we remember that three chariots could drive abreast upon the walls of Babylon, we realize the immense amount of asphaltum consumed in connection with their construction.

The Dead Sea was called in ancient times "Lacus Asphaltites."

(b) *Modern times, 1626 to 1893.*—The use of asphaltum became practically a lost art during the Middle Ages. The first mention of the subject, as far as I have discovered, was in 1626 in a German pamphlet upon "Hartz-Erde," (Pitch-earth). Dr. Amiess referred in 1692 to the deposits in Val de Travers, Switzerland. These deposits were subsequently fully described and uses suggested and tried by Dr. Erynis, from 1711 to the time of his death, 1736. He also discovered the asphaltic limestone of Lobsann, Germany. In 1802 the deposits of Seyssel, France, were discovered. The asphaltic limestone from Seyssel, was very successful for many years.

In 1832 Count de Sassenay united the asphalt interests of France and Switzerland. Paris adopted asphalt sidewalks in 1838. The engineer Merian developed compressed asphaltic limestone pavements in 1849. Soon afterward the eminent French engineer M. Leon Malo began his long and successful career in connection with asphaltic materials. Paris received its first successful asphalt street pavement in 1854; London, 1869; Buda-Pesth, 1871; Dresden, 1872; Hamburg, 1872; Berlin, 1873; Brussels, Geneva, Leipzig, Frankfort and others soon afterward.

The American cities were at first deceived, having expressed a desire for smooth, quiet pavements, and having heard of the asphalt pavements of Europe. The spurious article which encumbered our streets previous to 1873, was nothing more or less than coal-tar, sand and gravel.

Because of the difficulty of transporting the asphaltic limestone from Europe to America, inventors were encouraged to seek some durable substitute. Successful experiments made

between 1871 and 1873 in Newark, N. J., and New York City with an artificial mixture of Trinidad asphalt, residuum oil, limestone dust and sand, gave rise to the class of pavements now so successful, and called Trinidad asphalt pavements. In 1876 this pavement appeared in Washington as a pronounced success. In 1878 it became the standard pavement of Washington. It has been rapidly adopted by more than 71 American cities. It is being laid at the rate of about 140 miles annually.

Asphalt pavements in some form are found in 92 American cities. Leaving the statistics to the following Section VII., I will state that it is necessary to carefully select the materials and constantly supervise all asphalt constructions. It is necessary to examine very carefully the size and quality of the sand and limestone powder, as well as the asphalt and residuum oil to be used in pavements.

New and experimental asphalt pavements should not be tried at public expense.

VII. STATISTICS.

(a) *Mines, Europe and America.*—Inasmuch as detailed statistics are very uninteresting, I will give only summations and results.

A reference to Tables Nos. 2 and 3 under Section III., will show the location of the asphalt deposits of the world.

Inasmuch as no asphaltum is exported from the United States to Europe, it is best to confine our attention to that which is imported into this country or mined here. From 1867 to 1893 inclusive, there were unloaded at United States refineries 488,086 tons (2240 lbs. each) of Trinidad asphalt. During the past few years it has been arriving at the rate of about 70,000 tons of "Lake Asphalt" per year. This asphalt is from within the celebrated Asphalt Lake. From 1888 to 1892 some inferior "land" or "overflow" asphalt from outside of the Lake was imported. The variable impurities and lack of cementing qualities of this land asphalt injures it for engineering work and it is no longer imported.

The importations of asphaltic limestone, principally in the form of asphaltic mastic blocks or cakes, is very variable, rang-

ing from 900 tons to 20,000 tons per year. This comes principally from Sicily, France, Germany and Switzerland.

The output of the mines of asphaltic materials of the United States is very difficult to ascertain, because dissimilar materials have been grouped in the straggling reports heretofore obtainable, and because several mines are closed and others opened each year. As a whole, the asphalt *mining* industry of the United States is not a success. The demand for the class and quality of materials produced in our mines is far less than the available supply. Trinidad asphalt coming from a deposit large enough to warrant ample supplies of any amount and of constant quality, is used almost to the exclusion of all other asphalts. However, after careful experiment in due time our asphalt mines may become more valuable.

The total production per year of asphaltum, asphaltic sandstone, etc., from the U. S. mines has been within the last six years at the rate of about 42,000 tons. A reference to Section III., Tables Nos. 2 and 3, will indicate the location of the American as well as foreign deposits.

(b) *Pavements of Europe and America.*—I will dismiss this portion of the subject by briefly giving the latest statistics, January 1st, 1894. The asphalt pavements of all kinds in the United States and Canada on this date are as follows:

TABLE NO. 7.

KIND OF PAVEMENT.	Sq. Yds.	Miles.
Trinidad asphalt*	13,900,000	911.
Asphaltic limestone	151,000	10.
Asphaltic sandstone and other asphaltic materials, experimental and otherwise	619,000	41.
Totals	14,670,000	962.

N. B.—The above is street roadway pavements and does not include sidewalks.

* Subject to slight corrections from final 1893 reports.

The total asphalt pavements of European cities at the same date were as follows:

TABLE NO. 8.

CITY.	Sq. Yds.	Miles.
Berlin	1,280,796	83.
Paris	401,617	26.
London	370,000	24.
Other Cities	271,000	18.
Totals	2,323,413	151.

N. B.—In the preceding tables, the roadway is reduced to a common width of 26 feet for comparisons. The roadways themselves vary above and below this width.

The asphalt pavements of America have been laid within twenty years and those of Europe within the past forty years.

The civilization of cities can be gauged by the condition of their streets. The suppression of noise and dirt, made possible by asphalt pavements, in a great measure determines the character and progress of a city.

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